Cambrian Explosion

Cambrian Period: Facts & Information

Mary Bagley, LiveScience Contributor | March 21, 2013 02:25pm ET

<http://www.livescience.com/28098-cambrian-period.html>

Trilobite

Pin It Trilobites were the dominant species during the Cambrian Period, 540 to 490 million years ago. Credit: Bill Frische | ShutterstockView full size image

The Cambrian Period is the first geological time period of the Paleozoic Era (the “time of ancient life”). This period lasted about 53 million years and marked a dramatic burst of evolutionary changes in life on Earth, known as the "Cambrian Explosion." Among the animals that evolved during this period were the chordates, animals with a dorsal nerve cord; hard-bodied brachiopods, which resembled clams; and arthropods, ancestors of spiders, insects and crustaceans.

Though there is some scientific debate about what fossil strata should mark the beginning of the period, the International Geological Congress places the lower boundary of the period at 543 million years ago with the first appearance in the fossil record of worms that made horizontal burrows. The end of the Cambrian Period is marked by evidence in the fossil record of **a mass extinction event about 490 million years ago.** The Cambrian Period was followed by the Ordovician Period.

The period gets its name from Cambria, the Roman name for Wales, where Adam Sedgwick, one of the pioneers of geology, studied rock strata. Charles Darwin was one of his students. (Sedgwick, however, never accepted Darwin's theory of evolution and natural selection.)

Climate of the Cambrian Period--In the early Cambrian, Earth was generally cold but was gradually warming as the glaciers of the late Proterozoic Eon receded. Tectonic evidence suggests that the single supercontinent Rodinia broke apart and by the early to mid-Cambrian there were two continents. Gondwana, near the South Pole, was a supercontinent that later formed much of the land area of modern Africa, Australia, South America, Antarctica and parts of Asia. Laurentia, nearer the equator, was composed of landmasses that currently make up much of North America and part of Europe. Increased coastal area and flooding due to glacial retreat created more shallow sea environments.

Acorn worm fossil from Burgess shalePin It A fossilized Spartobranchus tenuis from the Burgess shale in Canada. The animal contains features of modern acorn worms and modern tube worms called pterobranches.

At this point, no life yet existed on land; all life was aquatic. Very early in the Cambrian the sea floor was covered by a “mat” of microbial life above a thick layer of oxygen-free mud. The first multicellular life forms had evolved in the late Proterozoic to “graze” on the microbes. These multicellular organisms were the first to show evidence of a bilateral body plan. These near-microscopic “worms” began to burrow, mixing and oxygenating the mud of the ocean floor. During this time, dissolved oxygen was increasing in the water because of the presence of cyanobacteria. The first animals to develop calcium carbonate exoskeletons built coral reefs.

The middle of the Cambrian Period began with an **extinction event**. Many of the reef-building organisms died out, as well as the most primitive trilobites. One hypothesis suggests that this was due to a temporary depletion of oxygen caused by an upwelling of cooler water from deep ocean areas. This upwelling eventually resulted in a variety of marine environments ranging from the deep ocean to the shallow coastal zones. Scientists hypothesize that this increase in available ecological niches set the stage for the abrupt radiation in life forms commonly called the “Cambrian Explosion.”

Fossils of the Cambrian Period--Scientists find some of the best specimens for the “evolutionary experiments” of the Cambrian Period in the fossil beds of the Sirius Passet formation in Greenland; Chenjiang, China; and the Burgess Shale of British Columbia. These formations are remarkable because the conditions of fossilization led to impressions of both hard and softbody parts and the most complete records of the varieties of organisms alive in the Cambrian Period.

The Sirius Passet formation has fossils estimated to be from the early Cambrian Period. Arthropods are the most abundant, although the groups are not as diverse as those found in the later Burgess Shale formation.

The Sirius Passet has the first fossil indications of complex predator/prey relationships. For example, Halkieria were slug-shaped animals with shell caps at either end. The rest of the body was covered in smaller armor plates over a soft snail-like “foot.” It is unclear whether they are more closely related to the annelids, such as modern-day earthworms and leeches, or are a primitive mollusk. Some specimens have been found in curled up defensive postures like modern pill bugs. Predator/prey relationships provide intensive selection pressures that lead to rapid speciation and evolutionary change.

Burgess Shale fossils are from the late Cambrian. Diversity had increased dramatically. There are at least 12 species of trilobite in the Burgess Shale; whereas in the Sirius Passet, there are only two. It is clear that representatives of every animal phylum, excepting only the Bryozoa, existed by this time.

ancient marine animals, ancient animal sight, development of eyesight, Anomalocaris, ancient predator, predator versus prey, evolutionary arms race, Cambrian explosion, Cambrian predators, trilobites, ancient crustaceans, crustacean evolutionPin It The fearsome meter-long super-predator Anomalocaris.

The largest predator was Anomalocaris, a free-swimming animal that undulated through the water by flexing its lobed body. It had true compound eyes and two claw-tipped appendages in front of its mouth. It was the largest most fearsome predator of the Cambrian Period, but did not survive into the Ordovician. The earliest known chordate animal, the Pikaia, was about 1.5 inches (4 centimeters) long. Pikaia had a nerve cord that was visible as a ridge starting behind its head and extending almost to the tip of the body. The fine detail preserved in the Burgess Shale clearly shows that Pikaia had the segmented muscle structure of later chordates and vertebrates. Haikouichythes, thought by some to be the earliest jawless fish, were also found in the Burgess Shale.

**A mass extinction event closed the Cambrian Period**. Early Ordovician sediments found in South America are of glacial origin. James F. Miller of Southwest Missouri State University suggests that glaciers and a colder climate may have been the cause of the mass extinction of the fauna that evolved in the warm Cambrian oceans. Glacial ice would have also locked up much of the free ocean water, reducing both the oxygen in the water and the area available for shallow water species.

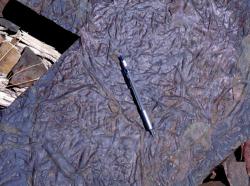
## Geology of the Cambrian Explosion

* [](http://ncse.com/image/olenoidesserratusburgessshale)October 17th, 2008 <http://ncse.com/evolution/geology-cambrian-explosion>

**Burgess Shale:***Olenoides serratus* from the Burgess Shale. Note the dark lines extending from the shell; these are rarely-preserved soft tissues, an indication of the unique preservation conditions of the Burgess Shale. Photo by Steven Newton.

The Cambrian Explosion (or Radiation) refers to a period of rapid diversification of the fossils found between ~530-520 Ma (millions of years ago). During this geologically brief period, fossils record a blossoming of animal life into complex organisms. Although the phyla of most of these animals appear to have originated before the Cambrian Explosion, it was during this time that they announce themselves in rocks worldwide.

Fossil locales such as Chengjiang and the Burgess Shale show a world of animals hunting and killing and defending themselves with ever-more complicated claws and teeth and eyes and armor. This is different from the soft-bodied world that existed prior to the Cambrian. The world following the Cambrian Explosion is our world.

[](http://ncse.com/image/wmtraceburrows)**Trace Fossils:***Planolites* trace fossils from the Middle Member of the Deep Springs Formation, just above the Cambrian-Precambrian boundary, White-Inyo Mountains, California. Photo by Steven Newton.

The Cambrian/Pre-Cambrian boundary is set at 542.0 ± 1 Ma by the first appearance of *Trichophycus pedum*, a mud burrower with complex movement. Animals existed prior to this time, but did not exhibit complex foraging behaviors.

The earliest animal fossils are the Ediacaran Fauna, which immediately preceded the Cambrian. There is considerable scientific debate about the nature of the Ediacarans. Most of these soft-bodied organisms lacked clear mechanisms of locomotion. The exact relationship of Ediacarans to modern animal phyla remains unclear.

Following the Pre-Cambrian-Cambrian boundary at 542 Ma, the subsequent twelve million years saw only modest increases in animal diversity. Rocks from this period record rich trace fossils, but few mineralized skeletons. The rapid diversification of animals began during the Tommotian period (530 Ma), and lasted 5-10 million years.

Molecular research suggests animals diverged into major groups far earlier than is shown in the fossil record. For example, Blair and Hedges (2005) put the split between echinoderms and hemichordates at 876 Ma, and Douzery et al. (2004) calculate the diversification of eukaryotes between 950-1,259 Ma. Thus, the major animal phyla may originate far earlier than the Cambrian Explosion. However, strata from these periods show no conclusive animal fossils at all. This issue is the subject of ongoing research.

## Timeline:

1. 850-630 Ma: Cryogenian Period

extensive world-wide glaciations

1. 630-542 Ma: Ediacaran fossils
2. 542.0 ± 1 Ma: Pre-Cambrian/Cambrian boundary
3. ~530 Ma: the Cambrian Explosion (Tommotian Age)
4. 525-520 Ma (Chengjiang fauna) and 505 Ma (Burgess Shale)  
     
   Fossil locales rich in complex animals, such as arthropods and chordates

## References

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* Douzery, E.J.P., et al., 2004. “The timing of eukaryotic evolution: Does a relaxed molecular clock reconcile proteins and fossils?” Proc. National Academy of Sciences, 101 (43): 15386-15391, 26 October 2004.

<http://www.fossilmuseum.net/Paleobiology/CambrianExplosion.htm>

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| The Cambrian Explosion | [http://www.fossilmuseum.net/images/VFMHome.jpg](http://www.fossilmuseum.net/index.htm) | Related interest: [Fossils of Chengjiang China](http://www.fossilmuseum.net/Fossil_Sites/Chengjiang.htm) [Cambrian Explosion Fossils of Utah](http://www.fossilmuseum.net/Cambrian-Explosion/Utah-Cambrian-Explosion.htm) [Fossils of the Burgess Shale](http://www.fossilmuseum.net/Fossil_Sites/burgessshale.htm) |
| [[Haikouella lanceolata primitive Chordates from Chenjiang](http://www.fossilmuseum.net/Fossil_Sites/Chengjiang/Xidazoon-Haikouella/XidazoonHaikouella.htm)](http://www.fossilmuseum.net/Fossil_Sites/Chengjiang/Xidazoon-Haikouella/XidazoonHaikouella.htm)Most major [animal groups](http://www.fossilmuseum.net/Tree_of_Life/kingdom_animalia.htm) appear for the first time in the fossil record some 545 million years ago on the [geological time](http://www.fossilmuseum.net/GeologicalTimeMachine.htm) scale in a relatively short period of time known as the Cambrian explosion. Of great worry to [Darwin](http://www.fossilmuseum.net/Evolution/Darwin.htm), the explanation of this sudden, apparent explosion persists as a source of numerous major debates in paleobiology. While some scientists believe there was indeed an explosion of diversity (the so-called punctuated equilibrium theory elaborated by Nils Eldredge the late Stephen J. Gould - Models In Paleobiology, 1972), others believe that such rapid acceleration of evolution is not possible; they posit that there was an extended period of evolutionary progression of all the animal groups, the evidence for which is lost in the all but nonexistent precambrian [fossil record](http://www.fossilmuseum.net/fossilrecord.htm). Early complex animals in the Paleozoic may have been nearly microscopic. Apparent fossil animals smaller than 0.2 mm have been found in the[Doushantuo Formation](http://www.fossilmuseum.net/Fossil_Sites/doushantuo.htm), China, forty to fifty-five million years before the Cambrian (Chen et al. 2004). Much of the early evolution could have simply been too small to see, much less preserve. Modern molecular technologies (genomics and other omics), through comparing nucleic acid and amino acid sequences across living species, are enabling the identification of genetic components and patterns stingily conserved by evolution, from those in which times of evolutionary branching of the tree of life can be inferred.  [[Earth's continents 550 million years ago](http://www.fossilmuseum.net/fossil-art/maps/gondwana/gondwana550mya.htm)](http://www.fossilmuseum.net/fossil-art/maps/gondwana/gondwana550mya.htm)The theory of the Cambrian Explosion holds that, beginning some 545 million years ago, an explosion of diversity led to the appearance over a relatively short period of 5 million to 10 million years of a huge number of complex, multi-celled organisms. Moreover, this burst of animal forms led to most of the major animal groups we know today, that is, every extant Phylum. It is also postulated that many forms that would rightfully deserve the rank of Phylum both[[Cambrian Fossils](http://www.fossilmuseum.net/Paleobiology/CambrianFossils.htm)](http://www.fossilmuseum.net/Paleobiology/CambrianFossils.htm) appeared in the Cambrian only to rapidly disappear. Natural selection is generally believed to have favored larger size, and consequently the need for hard skeletons to provide structural support - hence, the Cambrian gave rise to the first shelled animals and animals with exoskeletons (e.g., the [trilobites](http://www.fossilmuseum.net/Tree_of_Life/PhylumArthropoda/ClassTrilobita.htm)). With the innovation of structural support, the early Cambrian period also saw the start of an explosion in the size of many animals.  The Cambrian Explosion is the outcome of changes in environmental factors leading to changes in selective pressures, in turn leading to adaptive diversification on a vast scale. By the start of the Cambrian, the large supercontinent Gondwana, comprising all land on Earth, was breaking up into smaller land masses. This increased the area of continental shelf, produced shallow seas, thereby also expanding the diversity of environmental niches in which animals could specialize and [speciate](http://www.fossilmuseum.net/Evolution/speciation.htm).  **The debate persists today about whether the evolutionary "explosion" of the Cambrian was as sudden and spontaneous as it appears in the fossil record**. The discovery of new pre-Cambrian and Cambrian fossils help resolve the debate, as these transitional fossil forms support the hypothesis that diversification was well underway before the Cambrian began. More recently, the sequencing of the genomes of thousands of life forms is revealing just how many and what genes and the proteins they encode have been conserved from the Precambrian. The explosion of external form (the phenotype) in the [fossil record](http://www.fossilmuseum.net/fossilrecord.htm) is what we see now, but more gradual adaptation was taking place at the molecular level (the genotype). Wang et. al. (1999) for example, recently conducted phylogenetic studies divergences among animal phyla, plants, animals and fungi. These researchers estimate d[arthropods](http://www.fossilmuseum.net/Tree_of_Life/PhylumArthropoda.htm) diverged from more primitive [chordates](http://www.fossilmuseum.net/Tree_of_Life/PhylumChordata.htm) more than 900 million years ago, and Nematodes from that lineage almost 1200 million years ago. They furthermore estimated that the plant, animal and fungi Kingdoms might have split split from a common ancestors almost 1600 million years ago. Finally, they conjecture that the basal animal phyla ([Porifera](http://www.fossilmuseum.net/Tree_of_Life/Phylum-Porifera.htm), [Cnidaria](http://www.fossilmuseum.net/Tree_of_Life/PhylumCnidaria.htm), Ctenophora) diverged between about 1200 and 1500 million years ago. If their research is valid, at least six major metazoan phyla appeared deep in the Precambrian, hundreds of millions of years before the oldest fossils in the fossil record.  [[Primordial  G protein-coupled receptor](http://www.fossilmuseum.net/fossil-art/molecules/gprotein/gproteinreceptor.htm)](http://www.fossilmuseum.net/fossil-art/molecules/gprotein/gproteinreceptor.htm) Such estimates of ancient **divergence times could contain substantial error caused by uncertainty of the molecular clock assumptions**, confounding effects of horizontal gene transfer, and errors in estimating sequence homology (i.e., similarlity). Consequently, attempts to date evolutionary branchings with molecular clocks have resulted in widely different estimates among researchers. Despite disparities of estimates of divergence times, broad concensus exists that the developmental control henes such as HOX genes for metazoan body plans was well established prior to the Cambrian. If so, what is called the Cambrian Explosion was the consequence of selective pressures acting on this pre-existing "genomic toolkit". The novel life forms that [[Fruit fly homeodomain](http://www.fossilmuseum.net/fossil-art/molecules/homeodomain/homeodomain.htm)](http://www.fossilmuseum.net/fossil-art/molecules/homeodomain/homeodomain.htm)emerged represent existing genomic material being used in novel ways to control and regulate interlinked cascades of biological pathways during development, resulting in novel body plans and/or finer tuning of existing body plans to changing phyical, chemical and biospheric selective pressures. Only in recent years has science determined that developmental regulation proceeds through a sequential activation of series of regulatory switches that, in turn, activate networks of other genes. These regulatory genes produce proteins that bind to and affect the activity of other genes. The protein products of these genes then activate still other genes, and the cascade continues building an animal cell type by cell type in a distinct order. The best studied regulatory genes are the Hox genes that are so highly conserved as to predate the appearance of animals.  A facinating aspect of the Cambrian Explosion is its apparent speed over some 10 million years. From this it is reasonable to infer that expanded genomic complexity occured much earlier, perhaps over a billion years, prior to the morphological (phenotype) diversity that appeared in the Lower Cambrian. In recent years, research has shown that genomic complexity "happens" in many ways, including duplication and deletion of genes, cascades of genes, and, in complex organisms, entire chromosomes can be affected. Interesting also, is that such geneomic scrambling is an important mechanism in the etiology of cancers in animals.  Genomic diversity is, of course, the stuff (a toolkit) on which [natural selection](http://www.fossilmuseum.net/Evolution.htm) operates. The more numerous and complex enviroments and ecosystems provided the varying selective pressures to amplify benefitial mutation (genotypes) within populations, prune detrimental mutations, and otherwise fine-tuning genomes to enhance survival. Such fine-tuning would be different in different ecological niches.  Among the famous [Lagerstätten](http://www.fossilmuseum.net/Fossil_Sites/Lagerstatten.htm) from Cambrian time, the [Burgess Shale](http://www.fossilmuseum.net/Fossil_Sites/burgessshale.htm) of British Columbia, Canada and[Chengjiang Maotianshan Shales](http://www.fossilmuseum.net/Fossil_Sites/Chengjiang.htm), in Yunnan Province, China are the best known, having a great diversity of benthic or burrowing creatures, many of which are soft-bodied, lacking an exoskeleton. Less well known is that the American state of [Utah](http://www.fossilmuseum.net/Cambrian-Explosion/Utah-Cambrian-Explosion.htm) where similar Cambrian creatures are found. If fact, some researchers believe a larger number of species are to be found in the [Wheeler and Marjum Formations](http://www.fossilmuseum.net/Fossil_Sites/House-Range.htm) of Utah than in the Burgess Shale, though the fossils of soft-bodied animals in Utah are far less abundant and limited to relatively few horizons.  It is important to remember that geological history contains numerous periods of slow evolution punctuated by periods of rapid evolution, which Steven J. Gould called [Punctuated Equilibrium](http://www.fossilmuseum.net/Evolution/punctuated_equilibrium.htm). The rates of evolution generally depend on rates of selection, which in turn depend on rates of environmental change. It also depends upon the existing genomic diversity on which selection acts. Mutation rates tend to be slow and steady, and in the absence of environmental change, slowly accumulate in a population. It is selective pressure that weeds out the mutations that are detrimental or neutral to survival, and retains and applifies the mutations that are beneficial within a population. For a population isolated in a new environment, rapid selection can lead to speciation, and in the Lower Cambrian, to radically new forms that we now group in the Phyla of modern times occured to an unprecedented extent that has never since been repeated.  The years ahead should see furtherance of knowledge of how and the timeline along which the [Tree of Life](http://www.fossilmuseum.net/TreeOfLife.htm)branched, especially when proteomes of its many branches are unraveled**. In fact, the Tree of Life is a metaphore for what is actual a forest of trees. Still, major mysteries are likely to persist, given the amazing ability of nature to splice, dice, reassemble, swap, amplify, and silence or re-use nucleid acid sequences within the genome of living organisms.**  Also see: [Cambrian Explosion Information](http://www.cambrianexplosion.info/) | | |

<http://biologos.org/questions/cambrian-explosion#>

# Image for: Does the Cambrian Explosion pose a challenge to evolution?Does the Cambrian Explosion pose a challenge to evolution?

## In a Nutshell

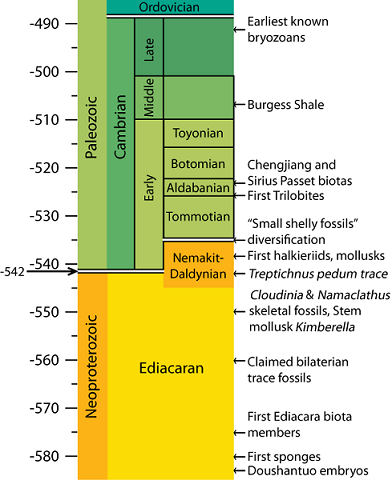
The “Cambrian Explosion” refers to the appearance in the fossil record of most major animal body plans about 543 million years ago.  The new fossils appear in an interval of 20 million years or less.  On evolutionary time scales, 20 million years is a rapid burst that appears to be inconsistent with the gradual pace of evolutionary change.  However, rapid changes like this appear at other times in the fossil record, often following times of major extinction.  The Cambrian Explosion does present a number of interesting and important research questions.  It does not, however, challenge the fundamental correctness of the central thesis of evolution.

[Previous Question](http://biologos.org/questions/complexity-of-life)[Next Question](http://biologos.org/questions/what-created-god)

## In Detail

The term “Cambrian Explosion” refers to the appearance and rapid diversification of most major living animal body plans (phyla) in the fossil record within an interval of perhaps 20 million years or less, a relatively short period in evolutionary history. This time is known as the Early Cambrian, and began around 543 million years ago. This time interval is recorded by some spectacular fossil deposits that include superbly preserved fossils of these early animals. Two famous examples are the Burgess Shale in Canada, and the Chengjiang in China.1 Despite the claims of some, the Cambrian was not the beginning of multicellular animal life; the latter has a fossil record that extends back at least 30 million years earlier.2

The Cambrian Explosion is often posed as a challenge for evolution because the sudden burst of change in the fossil record appears to be inconsistent with the more typical gradual pace of evolutionary change. However, although different in certain ways, there are other times of very rapid evolutionary change recorded in the fossil record -- often following times of major extinction. The Cambrian Explosion does present a number of challenging and important questions because it represents the time during which the main branches of the animal tree of life became established. It does not create a challenge to the fundamental correctness of the central thesis of evolution, the descent of all living species from a common ancestor. This important period in the history of life extended over millions of years, plenty of time for the evolution of these new body plans (phyla) to occur. Furthermore, the fossil record provides numerous examples of organisms that appear transitional between living phyla and their common ancestors. The ongoing research about the Cambrian period is an exciting opportunity to advance our understanding of how evolutionary processes work, and the environmental factors shaping them. [or shaping our thoughts to a designers input]

The major animal body plans that appeared in the Cambrian Explosion did not include the appearance of modern animal groups such as: starfish, crabs, insects, fish, lizards, birds and mammals. These animal groups all appeared at various times much later in the fossil record.3 The forms that appeared in the Cambrian Explosion were more primitive than these later groups, and many of them were soft-bodied organisms. However, they did include the basic features that define the major branches of the tree of life to which later life forms belong. For example, vertebrates are part of the Chordata group. The chordates are characterized by a nerve cord, gill pouches and a support rod called the notochord. In the Cambrian fauna, we first see fossils of soft-bodied creatures with these characteristics. However, the living groups of vertebrates appeared much later. It is also important to realize that many of the Cambrian organisms, although likely near the base of major branches of the tree of life, did not possess all of the defining characteristics of modern animal body plans. These defining characteristics appeared progressively over a much longer period of time.4

### Interpretations of the “Cambrian Explosion”

Not all scientists accept the idea that the Cambrian Explosion represents an unusually rapid evolutionary transition. **The fossil record is notoriously incomplete, particularly for small and soft-bodied forms**. Some researchers argue that the apparent rapid diversification of body plans is an artifact of an increase in the rate of fossilization, due in part to the evolution of skeletons, which fossilize more effectively.5 Many of the early Cambrian animals possessed some type of hard mineralized structures (spines, spicules, plates, etc.). In many cases these, often very tiny, mineralized structures are all that are found as fossils. There were major changes in marine environments and chemistry from the late Precambrian into the Cambrian, and these also may have impacted the rise of mineralized skeletons among previously soft-bodied organisms. 6

Most scientists **are persuaded that something significant happened at the dawn of the** Cambrian era and view the Cambrian Explosion as an area of exciting and productive research. For example, scientists are now gaining a better understanding of what existed before the Cambrian Explosion as a result of new fossil discoveries. Recent discoveries are filling in the fossil record for the Precambrian fauna with soft-bodied organisms like those in the Ediacaran Assemblages found around the world.7 Late Precambrian fossil discoveries also now include representatives of sponges, cnidarians (the group that includes modern jellyfish, corals and anemones), mollusks and various wormlike groups. Some of the new fossil discoveries, in fact, appear to be more primitive precursors of the later Cambrian body plans. The discovery of such precursors shows that the Cambrian organisms did not appear from thin air.8 Further discoveries will no doubt reveal more clearly the relationship of Precambrian organisms with the creatures found in the Burgess Shale and Chengjiang deposits.9

Genomic studies provide further insights into the origins of the Cambrian Explosion. Although the genetic divergence of organisms would have preceded the recognition of new body plans in the fossil record, accumulating genomic data is broadly consistent with the fossil record.10 Both point to the rise of the bilateria (bilaterally symmetric invertebrate animals) in the latest Precambrian Ediacaran, and their ecological explosion in diversity in the Cambrian.

### Unanswered Questions

The sudden change of the Cambrian Era was, in relative terms, not too sudden for the process of evolution. The changes during the Cambrian Era did not occur over decades, centuries, or even thousands of years; they occurred over millions of years—plenty of time for evolutionary change. However, for millions of years beforehand, body plans of animals had remained relatively constant. Not until this time period did a significant change occur. The remaining questions are: What triggered the Cambrian Explosion? And why did so much change occur at this time? Several different theories address the origin of the Cambrian Explosion**, proposing that dramatic environmental changes must have opened up new niches for natural selection to operate upon. These proposals include the runaway glaciation theory,11which proposes that glaciers briefly covered much of the earth, and the resultant loss of habitat created bottlenecks where evolution could act more rapidly. Another theory suggests that a change in atmospheric oxygen led to this sudden burst in evolutionary changes.12 Yet another proposal is that major changes in the seafloor, from algae mat-covered surfaces in the late Precambrian to soft muddy bottoms later in the Cambrian, had dramatic evolutionary and ecological impacts.13**

### The Cambrian Era Fossils, Providing Answers

While the causes of the Cambrian Explosion remain a topic of open and exciting debate, the continued fossil discoveries from the Cambrian and Precambrian Eras are bringing more clarity to the evolutionary puzzle. These fossils provide valuable insight, particularly for envisioning the common ancestors of diverse groups. For instance, both vertebrates (fish) and echinoderms (sea urchins, starfish) are part of the group called deuterostomes. Without fossil evidence, it is hard to envision what a common ancestor would look like for these very different creatures. The Cambrian fossils are filling in the picture.14

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### Books

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### Online

* Conway Morris, Simon. The Cambrian Explosion. Course, September 16, 2007. From [The Faraday Institute of Science and Religion, MP3, Download Video](http://www.st-edmunds.cam.ac.uk/faraday/Multimedia.php). (accessed December 18, 2008).

## Notes

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